DRIVER ASSISTANCE THROUGH LIGHTING

Dr. Burkard Wördenweber
Hella KG Hueck & Co., Germany, 476

ABSTRACT

Headlamps are the primary active safety device for over 25 % of the vehicle operating time. During twilight and night the driver relies on the headlamps for safe guidance, that is for both visual tracking and obstacle detection. The dynamic nature of driving requires adaptive lighting. Technology can supply practical solutions now. The paper describes both the new qualities and the underlying technologies of adaptive headlamps.

INTRODUCTION

The development of intelligent driver assistance systems in the vehicle does not aim to remove the responsibility from the driver, but merely to support him by taking some of the stress of driving away from him. Some of the more mundane tasks, such as changing gear or controlling the heating are taken away from him. Besides providing more comfort, the driver is able to focus all of his attention on the traffic and his own and other peoples safety.

TRAFFIC AND VISION

The human being has been called a "seeing animal". M. Sivak establishes the fact that 84 % of the work performed by the human senses in road traffic is concerned with vision. Our eyes are the most important sensors that determine our ability to drive, to react in traffic and to steer our vehicles safely.

The Visual Channel

The brain is often compared with a neural network. The information from the eye passes through a complex visual channel. With each stage information is abstracted and knowledge on the context of the scene accumulated.

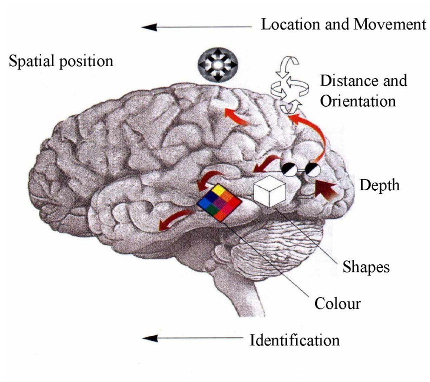

Fig. 1: Visual channel

The following stages are know:

v1 rough shapes
v2 stereo vision
v3 depth and distance
v4 colour
v5 movement
v6 spatial position

It is believed that the visual channel passes through v1 - v2 and then bifurcates into the channel for location and movement (v3 - v5 - v6) and identification (v4). The sequence and the time taken in the vision process are significant for driving. For example it takes roughly 120 m sec to detect a shape by its contour. The recognition of colour has to wait for nearly 400 m sec.

Safety and Comfort

It is well known that vehicle lighting is a precondition for safe driving at night. It is now also becoming widely accepted that lighting also plays a role in making driving a more comfortable and stress free occupation.
The studies were done by the "Auto, Sicht, Sicherheit" Research Group (ASS) in Cologne and Daimler Benz Forschung

Fahrzeug, Abteilung Mensch und Fahrzeug in Berlin. Using headlamps with an emphasized close-range illumination area, as in the H4 system used here, a shift of vision towards the vehicle can be seen. The width of the 90 % area is also restricted on account of the "narrow" light distribution. Exactly the opposite can be seen in the case of the Xenon headlamp with its ellipsoid system and wide field of illumination at the cut-off line, whereby the 90 % area is substantially widened. The driver thus "scans" the more distant areas more intensely.

Digital Information

Vehicle traffic is now becoming increasingly charted. Digital maps provide map data, which is accurate enough to provide curve radii even for lighting. With the assistance of the global positioning system (GPS) the absolute coordinates, speed and direction of the vehicle becomes known to system and driver. Intervehicle communication and a growing infrastructure of mobile communication will lead to on-line information on traffic and road.

ROAD ILLUMINATION

Vehicle lighting falls into two categories, the headlamps and the signal lights. The headlamps illuminate the road whilst the signal lights make the vehicle visible at night and also indicate driver intentions such as turning or stopping.

Adaptive lighting

The aim of the European Research Project AFS, Advanced Front Lighting System (Eureka-Project 1403), joins car manufacturer, set makers and bulb manufacturers in their effort to establish a new lighting system. By around 2005 they hope to have replaced the now standard low- and high beam by a more adaptable set of lighting functions from bending light, town light, country light, motorway light to adverse weather light.

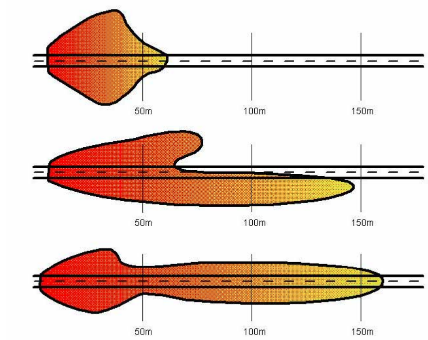

Fig. 2: Future adaptive headlamp light patterns: town light (top), country light (mid), motorway light (bottom)

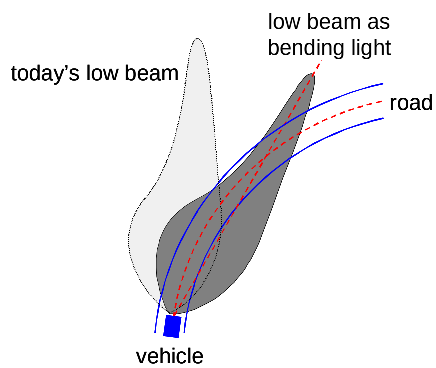

Fig. 3: Dynamic bending light

Mechatronic Systems

No driver is willing to have to switch between more than the three lighting function we have today. Any adaptive lighting system will therefore have to be automated. The system relies on information on vehicle speed, acceleration, curvature, ambient lighting conditions, weather, road conditions or road type. Some, if not most of this information is available on the car-area network, or CAN-Bus. Other information can be gained from additional sensors.

Besides running the light sources, the controls of a future headlamp will also have to drive a number of actuators, such as stepper motors, solenoids or piezo actuators. For example, in order to move the light into a bend the control unit has to compute the right angle for the swivel motion of the 'bending light' function. For this it takes the steering angle, the speed and the vehicle rotation around its vertical axis. It may also receive predictive information on a most likely path from the vehicles' navigation system or a prediction from an on-board camera system.

Bi-Xenon

At the heart of many modern headlamps is a gas-discharge light source, known as Xenon light, in a projector module. The same module also comes with an actuator for dual-mode operation. This Bi-Xenon module provides both high and low beam and thus leaves more space for additional lighting functions.

Vario-Xenon

The Vario-Xenon module offers even more functionality than Bi-Xenon. Instead of two states it can vary light distributions continuously as well as offer further discrete states. Its projection system contains a rotating shield, with a free-form geometry inscribed on its basic cylindrical shape. The envelope of the shield in the projection creates the cut-off of the light distribution. One such shield can hold the cut-off for a town-light, country-light, motorway-light and a high beam.

Dynamic curve lighting

Today the low beam is fixed with the vehicle body. When the car enters a bend, the light travels straight ahead illuminating roadside and verges. Legislation is being changed to permit the low beam to take bends into account in future. Due care has to be taken to maintain low glare for oncoming traffic and not to distract the driver.

AFS headlamp

An AFS headlamp is a multifunctional system to illuminate the road in varying driving conditions automatically. For example, it will take account of adverse weather, such as wet road conditions, and reduce road-reflected glare to oncoming vehicles and increase the illumination of roadsides and road markings to assist driver orientation.

Beam orientation

Control in relation to the vertical vehicle axis is a component of the dynamic bending lighting planned for AFS. Series production and use of such systems can be expected beginning in about the year 2003, since the regulations will have to be adapted to accommodate them. The current approach to control of dynamic bending headlamps presupposes information through yaw and steering angle sensors. Future control systems will also have access to data on the course of the road in front of the vehicle.

Control and steering of movements about the longitudinal axis is not important in automobiles, although it could make a significant contribution to motorcycle safety. A prototype developed by Hella demonstrated its performance capability in the Daimler Benz research vehicle F 300 Life-Jet, which was introduced to the public at the IAA 97.

Automatic headlamp levelers already realize control about the transverse axis of the vehicle today. Dynamic headlamp levelers - used particularly in combination with Xenon headlamps - compensate not only various load states, but pitching movement as well, for instance during acceleration and braking. A more precise analysis of the reactions of these systems reveals that the axle sensors currently used to obtain control information are only capable of determining the position of the vehicle in relation to the road in the area immediately adjacent to the vehicle, so that the headlamp ranges set near hilltops and dips are either too great or too small. Just as with the vertical axis, only sensors that see what is coming can provide perfect results.

Anticipatory beam control

AFS for the first time will permit forward lighting to become adapted to the road- and traffic conditions in front of the vehicle. Vehicle sensors today provide real-time information on the vehicle condition such as speed, acceleration. With a record of the recent history a predictive beam control can be implemented. There are, however, exceptions. For example, the change in curve radius can be predicted reasonably accurately using the mathematical model of road curves (2nd derivative is constant). The beginning of a curve is not predictable without prior information. Such information could come from either forward-looking sensors of digital maps in conjunction with a global positioning system.

Pixel headlamp

New technologies in optical sensing, telematics and digital lighting devices will make it possible to design fully dynamic headlamps. Sensor information on vehicle dynamics, the road environment, traffic, visibility and weather conditions will enable driver assistance well beyond what we know today. Electronic light sources and digitally controlled optics, such as digital mirror or liquid crystal devices will extend the functionality of the actuators used today. Thus new functionality such as 'anti-glare' or selective illumination will become possible. Until then, however, a fair amount of research into the psychology of vision in a dynamic environment will have to be completed.

COMFORT

Interior lighting system

Lighting for the vehicle interior is primarily a function of comfort and safety. In high-end vehicles the number of light sources exceed that of the average household. The simple switches or door contacts are no longer sufficient to control lighting. Systems for automatic light control know the state of the vehicle, switch lights as required and provide smooth transitions with little irritation to driver or passenger.
For effective control, the lights are grouped in functional clusters.

Courtesy lighting

Entry and exit lighting is located on the exterior of the vehicle in, for example, the door handles or the exteriour mirrors, or on the door sill or in the door frame itself. It illuminates the pavement on approach and the door area on entry.

Fig. 4: light sources in the vehicle

Orientation lighting

Orientation lighting is a low level illumination for safety devices, such as door release or belt buckle. Also the glove compartment, side pockets or foot well may be illuminated. In people movers or vans, low level lighting for sleeping passengers or playing children may be required.

Functional lighting

Traditionally interiour lighting was limited to one or more reading lamps. These functional lamps have improved in quality and now provide virtually glare free illumination and may, in case of mobile offices, even be designed to offer shadow free lighting.

Ambient lighting

Ambient lighting is a continuous, low-level illumination of the passenger space. It provides both a feeling of space and wellness.

Interiour light control

Control systems for interiour lighting rely on a number of input in order to determine the current lighting requirements. Such inputs include:

- Door contact for entry and exit,
- Ignition on/off,
- Airbag or crash sensor, burglar alarm for emergency situations,
- Central locking,
- Light sensor for ambient lighting and directional lighting,
- Temperature and rain sensor,
- Speed.

COMMUNICATION IN TRAFFIC

The human being is able to absorb information at the rate of approximately 16 bits/second, of which a bandwidth of 8 - 10 bits/second is generally utilized in normal activities. The observer perceives simple messages, which furthermore are presented very succinctly in terms of shape, comprehensively "almost instantaneously". The processing time for simple messages is 1/10 to 1/5 of a second. For absorbing more complex messages 35 - 60 % of the information is redundant and looks for a common means of expression for signs and signals.

Contour Lighting

Contours are the most natural marker for objects. The human vision system is programmed to detect contours rapidly. Contour lighting improves the detection and recognition. Vehicles marked with contour lighting are easier to see particularly in situations of low contrast, such as fog. Lighting technology has advanced to make contour lighting attractive w.r.t. styling and pricing.

Signal Lighting

Rear-combination lamps on cars today comply with legal regulations, which date back almost 50 years. Small modifications over the years include the addition of fog lamps and high-mount brake lamps. The luminous intensities are still not defined universally and it is common to find a tail lamp on one vehicle being effectively brighter than a stop lamp on another vehicle.

Fig. 5: Contour making to enhance visibility

With new technology and, in particular, with significantly more information in the vehicles there is considerable scope for improvement.
The following improvements have the charm of being intuitively acceptable:
Additional warning for emergency braking,
Automatic signal to safeguard an accident,
Brake-force display and
Universally defined luminous intensities for tail and brake function.

Fig. 6: brake force display (photo curtesey of BMW “sculpture”)

EXCEPTIONS

Most of the ambient information drivers have to sense and process in order to drive a vehicle safety through traffic is visual in nature, i. e. is input through the eyes. The human eye, and above all the subsequent information processing in the brain, is well-adapted to this task, although the system is sometimes ill-equipped to handle conditions of poor visibility, as seen in accident statistics. In Germany, for instance, about half of the accidents (49.6 %) in 1993 occurred at night. To understand the significance of these figures, it must be remembered that only about 20 - 25 % of total driving time is at night.
Extensive work in order to provide additional information to the driver and assist in accident avoidance is required. The following section summarizes the work on optical sensors for this purpose.

Light and rain sensor

The light sensor is one of the simplest and most effective sensors for driver assistance. The light sensor measures the ambient lighting conditions and compares them to fore field luminance. This information is then used to switch the driving lights automatically. At the same time the information is used in applications such as displays and climate control. The light sensor is best located behind the windscreen in an area covered by the wipers. The location is also ideal for a rain sensor. This sensor controls the operation of the wiper and thus takes away one of the menial driving tasks.

Lane Position

The lane-position sensor is another effective component for driver assistance. In this case an infrared light source illuminates the ground next to the vehicle. A photo-diode array picks up the reflection and detects the lane markings. This information is used to provide the driver with, for example acoustic, feedback when he or she inadvertently leaves the lane.

Road condition

The detection of water or ice on the road allows an estimation of the frictional coefficient of the road. A road-condition sensor provides information on speed limits due to limited road holding. The information is also useful in conjunction with ABS or ESP systems.

Viewing distance

Infrared lasers used for automatic cruise control or pre-crash sensing can also provide information on a number of other conditions. One such information is the approximate viewing distance. The sensor is best placed in the headlamp itself. The IR signal and its reflection are timed and thus give distance information on near-by objects and even fog.

Forward looking sensor

Modern camera technology is beginning to provide cameras with a highly dynamic operating range and in-build processing power. CMOS cameras can operate at low light levels and are still able to compensate glare. Picture processing is beginning to allow real-time detection of lane markings. In conjunction with infrared lighting a close-loop light control for forward lighting is now technically possible.

REFERENCES

Sivak, M: “The information that drivers use: is it indeed 90 % visual?”, Perception, Vol. 25, 1996, pp. 1081 – 1089

Statistisches Bundesamt Wiesbaden: „Straßenverkehrsunfälle 1993 in Deutschland“. Verlag Metzler-Poeschel, Stuttgart

„Night Time Traffic Accidents, Trends and Characteristics”, OWL Congress for Safety, 1993

Dorissen, H. T., Hoever, N.: „By far the best – keeping cruising distance”, Hella Lighting Technology R & D Review 1996, pp. 78 – 86

Damasky, J., Hosemann, A.: “A good guide – how good headlamps encourage the eye to scan for danger”. Hella Lighting & Electronics R & D Review 1997, pp. 57 – 63

Lachmayer, R.: “Light plax – sensors and actuators adapt headlamp functions”, Hella Lighting Technology R & D Review 1996, pp. 87 – 92

Wördenweber, B., et. al.: „R & D Review 2000“